CONFIDENTIAL

FIFTH INTERIM REPORT

on the

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

[redacted] ILLEGIB

PERIOD: December 1, 1956

to

January 1, 1957

REFERENCE: [redacted] 25X1

[redacted] 25X1

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/04/10 : CIA-RDP78-03424A000500010016-0

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

The following letter is submitted to report on the progress and activity in the VLF antenna development program for the period December 1, 1956 to January 1, 1957. The proposed methods for the development of a receiving antenna with a bandwidth of 2 kc and a center frequency of approximately 25 kc were described in detail in a "Proposal for VLF Antenna Development" which was submitted by [redacted] of [redacted] and was designated by [redacted] dated July 1956. 25X1

I. PERSONNEL: [redacted] 25X1

184 hours 25X1

25-1/4 hours

136 hours 25X1

II. TRIPS AND CONFERENCES

None

III. ACTIVITIES

A final report is being prepared which will summarize the results of the VLF Antenna Development Program. This report consists primarily of an analytical appraisal of the relative merits of the ferrite cored loop as a very low frequency receiving antenna. The restrictions imposed upon the antenna, briefly, are that it operate at 25,000 cps and have a 3 db passband of 2000 cps. The basis used for judging the relative merits of a ferrite antenna is that of comparison of induced voltages and signal-to-noise ratios with an air core loop antenna of comparable maximum dimension. Comparisons made are primarily analytical with experimental checks whenever feasible.

The table of contents of the report is given below:

The report is approximately 90 per cent complete at this time and should be ready for delivery by February 15, 1957.

The expenditure of manpower was greatest during the fabrication of certain ferrite cored antenna configurations during September and October 1956, and at the present time has been reduced to a low level. A small amount of data is still being taken on ferrite cores to provide substantiation for theory prepared for the VLF Antenna Report.

25X1

FOURTH INTERIM REPORT

on the

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

PERIOD: November 1, 1956

to

December 1, 1956

REFERENCE: [redacted] 25X1

This is an advance copy

[redacted] 25X1

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

The following letter is submitted to report on the progress and activity in the VLF antenna development program for the period November 1, 1956 to December 1, 1956. The proposed methods for the development of a receiving antenna with a bandwidth of 2 kc and a center frequency of approximately 25 kc were described in detail in a "Proposal for VLF Antenna Development" which was submitted by [redacted] and was Designated by [redacted] dated July 1956.

25X1 25X1 25X1 25X1

I. PERSONNEL:

[redacted] 25X1

144 hours

86 hours

88 hours

II. TRIPS AND CONFERENCES:

None

III. ACTIVITIES:

EXPERIMENTAL - in connection with the preparation of a final report, measurements were made to determine the effect of single layer winding coil length for a fixed core length. The literature is not clear on this point. Seemingly contradictory results are only partially resolved by considering differences in specific antenna requirements. Our experiments are based on power output measurements which under certain conditions are equivalent to signal-to-noise measurements. Results indicate power output (at a fixed $f_o/\Delta f$) increases as the coil to core length ratio approaches 1. The effect described by Belrose[1] for small ratio values was not found. As a result actual signal-to-noise measurements are being undertaken to substantiate the validity of measurements made on the basis of power output.

ANALYTICAL - A final report is being prepared which will summarize the results of the VLF Antenna Development Program. Included in this report will be a discussion of the material and geometric requirements imposed on a ferrite rod antenna in order for it to compete with air core loop antennas; empirical results comparing various ferrite rod antenna configurations with air core loop antennas; a discussion of some noise problems as they affect ferrite rod antenna design. Briefly, the conclusions reached indicate the relative advantages of ferrite rod antennas over air core loop antennas are based primarily on the importance, in a particular application, of a line configuration over a plane area configuration.

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1 "Ferromagnetic Loop Aerials" by J.S. Belrose, W. Engr. February 1955

Report Prepared by:

25X1

Report Reviewed by:

25X1

File
RD107
Task ~~#3~~ 4

THIRD INTERIM REPORT

on the

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

PERIOD: October 1, 1956

to

November 1, 1956

REFERENCE: [redacted] 25X1

[redacted] 25X1

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

The following letter is submitted to report on the progress and activity in the VLF antenna development program for the period October 1, 1956 to November 1, 1956. The proposed methods for the development of a receiving antenna with a bandwidth of 2 kc and a center frequency of approximately 25 kc were described in detail in a "Proposal for VLF Antenna Development" which was submitted by [redacted] and was Designated by [redacted] dated July 1956. 25X1 25X1 25X1 25X1

I. PERSONNEL:

[redacted] 25X1

[redacted]	160 hours
	102 hours
	100 hours
	52 hours
	73 hours

II. TRIPS AND CONFERENCES:

A meeting was held on October 25, 1956, between representatives of [redacted] and the contracting agency. The following persons were in attendance. 25X1

1. Contracting Agency
   Section head
   Project engineer

2. [redacted] 25X1

The relative merits of a ferrite cored loop antenna and an air core loop antenna were discussed on the basis of effective height as a merit factor. A model of a ferrite cored antenna which would produce a greater effective height than an air core antenna of the same volume was displayed.

A second meeting was held on November 5, 1956 between representatives of [redacted] and the contracting agency. The following persons were in attendance. 25X1

1. Contract Agency
   Project Engineer

2. [redacted] 25X1

Subsequent to the October 25, 1956 meeting, the use of the "effective height" as a merit factor was reviewed. If the antenna output is to be used directly as an input signal to the grid of a vacuum tube then the largest "effective height" for a given bandwidth is the desired figure of merit. However, if the signal is to be transferred to a remote point by means of a low impedance cable then the power output which can be delivered into the low impedance (72 ohms) is the important criterion. On this basis, the model ferrite loop which was available at the October 25, 1956 meeting is not very satisfactory. The power output of the research model ferrite cored device (5 cores 8 inches long by 1/4 inch diameter) is 3.75 microwatts whereas an equivalent volume air core loop

No Power output is always better if Transformer can be used for impedance matching. This change confirmed by Phone call to [redacted] 25X1 30 Nov 1956 had a power output of 8 microwatts for the same field strength and 2 kilocycle bandwidth.

Ferrite cores which were developed by [redacted] 25X1 [redacted] 25X1 were also displayed. These cores are 15 inches long and 7/16 inches in diameter and have an intrinsic permeability of approximately 300 at 25 kilocycles. One of these large cores gives a power output of 3.6 microwatts as versus the 8 microwatts quoted previously for the air core loop. The general conclusion that a ferrite cored antenna, even is $\mu_i \rightarrow \infty$, would have no greater output than an air core antenna of comparable maximum dimension was presented. Thus a ferrite rod antenna 15 inches long would be about equivalent to an air core loop antenna 15 inches in diameter. The ferrite rod gives a different package but no significant advantage on power output for a given maximum dimension.

After this appraisal of the use of ferrite cores in loop antennas, the customer's project engineer indicated that the requirement for the delivery of a VLF antenna system would be reviewed, ~~deleted and that instead a technical report describing the use of ferrite in loop antennas would be substituted.~~

Note This change confirmed by phone call Nov 30, 1956 with [redacted] 25X1

III. WORK DONE DURING PERIOD:

Since two meetings were held at the end of this work period the progress is described in Section II of this report. To further substantiate the results presented in Section II, the equation for the power output will be given

$$P_o \sim \frac{(e_i)^2 Q}{L}$$

where

P_o = signal power output

e_i = induced voltage proportional to μ_e (effective core permeability) times A (core area) times N (turns on core)

L = coil inductance proportional to $\mu_e A N^2$

The conclusion after substituting μ, A, and N into the power output equation is that for a given bandwidth (Q), that

$$P_o \sim \mu_e A .$$

Thus the number of turns is not important except as an impedance matching adjustment.

Since a ferrite core loop can have a substantially higher Q than an air core loop of comparable maximum dimension it appears that ferrite cored antennas are particularly suitable for narrow band applications. If square pass-band resonant circuits could be obtained then the use of stagger-tuned high Q loops could result in substantially better performance for ferrite cored high Q antenna systems. The square pass bands would be necessary to prevent interaction among the many stagger tuned circuits if all loops were put on the same core. Since no method is known for obtaining a square pass-band this is not a practical solution. Another approach would be to use highly dispersive material to make a single high Q circuit cover a wide band of frequencies. Since dispersion is usually associated with loss, the possibility of obtaining useful dispersive effects simultaneously with high Q is not good with presently available materials.

25X1

file / RD107
TO # 4

SECOND INTERIM REPORT

on the

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

PERIOD: September 1, 1956

to

October 1, 1956

REFERENCE:

25X1

25X1

Declassified in Part - Sanitized Copy Approved for Release 2012/04/10 : CIA-RDP78-03424A000500010016-0

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

The following letter is submitted to report on the progress and activity in the VLF antenna development program for the period of September 1, 1956 to October 1, 1956. The proposed methods for the development of a receiving antenna with a bandwidth of 2 kc and a center frequency of approximately 25 kc were described in detail in a "Proposal for VLF Antenna Development" which was submitted by [redacted] 25X1
and was designated by [redacted] dated July, 1956. 25X1

I. PERSONNEL: [redacted] 25X1

25X1

[redacted]	88 hours
	178 hours
	178 hours
TOTAL	444 hours

II. TRIPS AND CONFERENCES: None

III. WORK DONE DURING PERIOD:

The VLF Antenna development work to date has been devoted to the assimilation and evaluation of several antenna configurations which make use of the high permeability and low conductivity properties of ferrite materials. During the first month, the suitability of various types of ferrite materials was examined by experimentation. During this second month, parallel analytical and experimental efforts were expended on the electrical design problem. Preliminary results, thus obtained, have served to point up basic differences in the several configurations considered and have permitted the selection of one configuration as the best of the group. This antenna is referred to as the series-tank antenna, ST antenna.

Measurements on the ST antenna indicate a three rod unit (8" x 1/4 dia. rods spaced 3/4" on center) should be equivalent in sensitivity to a 500 turn - 144 sq. in. air core loop.

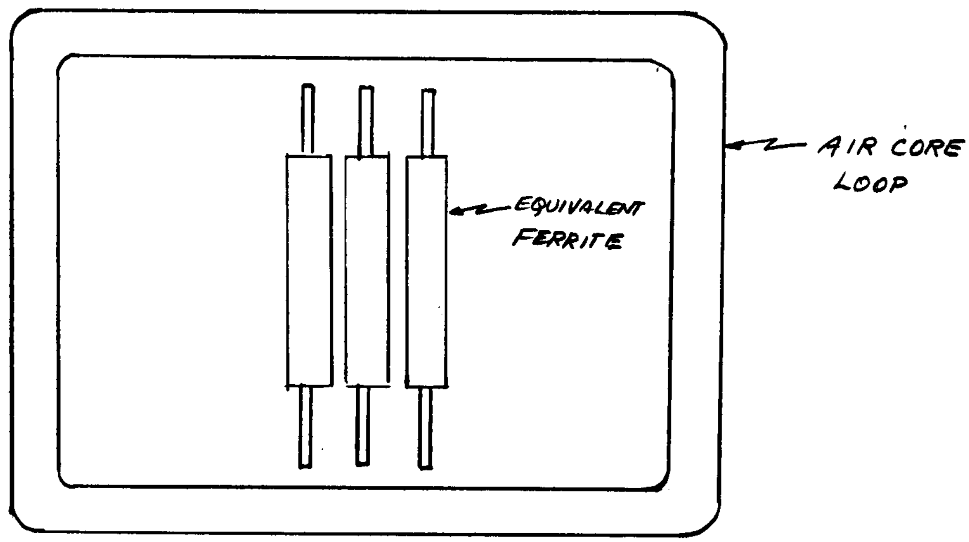


Figure 1

Relative Sizes of Loop and Ferrite Antenna

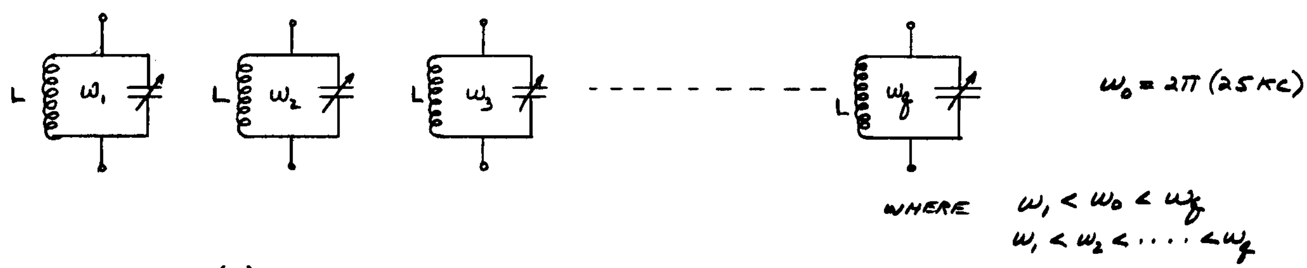
Effective Height: Ferrite, h ≅ 1.9 cm.

Loop , h ≅ 1.6 cm.

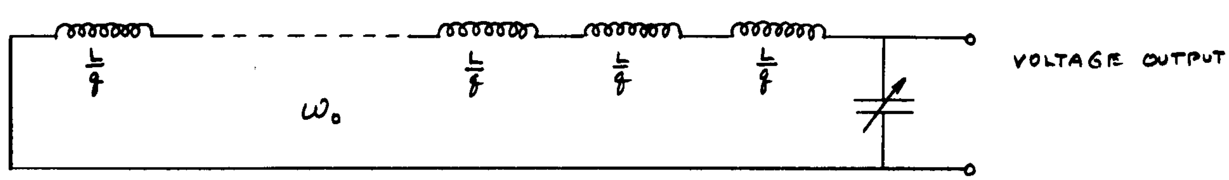
A 24 rod ST antenna is being constructed. As presently evisaged the prototype will resemble three ladder sections parallel to each other and spaced several inches apart during operation, yet collapsable when not is use. The collapsed dimensions are in the order of 4" x 10" x 15". It is expected that this 24 rod antenna optimum design will excel the previously mentioned air core loop by a factor of approximately five.

The following briefly describes the antenna systems that have been investigated along with a summary of the relative merits of each.

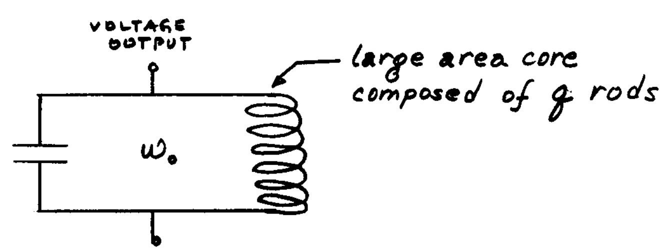
(A) This configuration consists of a system of high-Q (125), narrow band (200 cps) antennas each resonated at a different frequency in the passband and conductively isolated from each other by 4 tuned-output (230 cps band pass) preamps. These transistor preamp-outputs are combined in a parallel fashion in a summing amplifier so that each of the narrow bands add up to provide the required 2000 cps band pass.



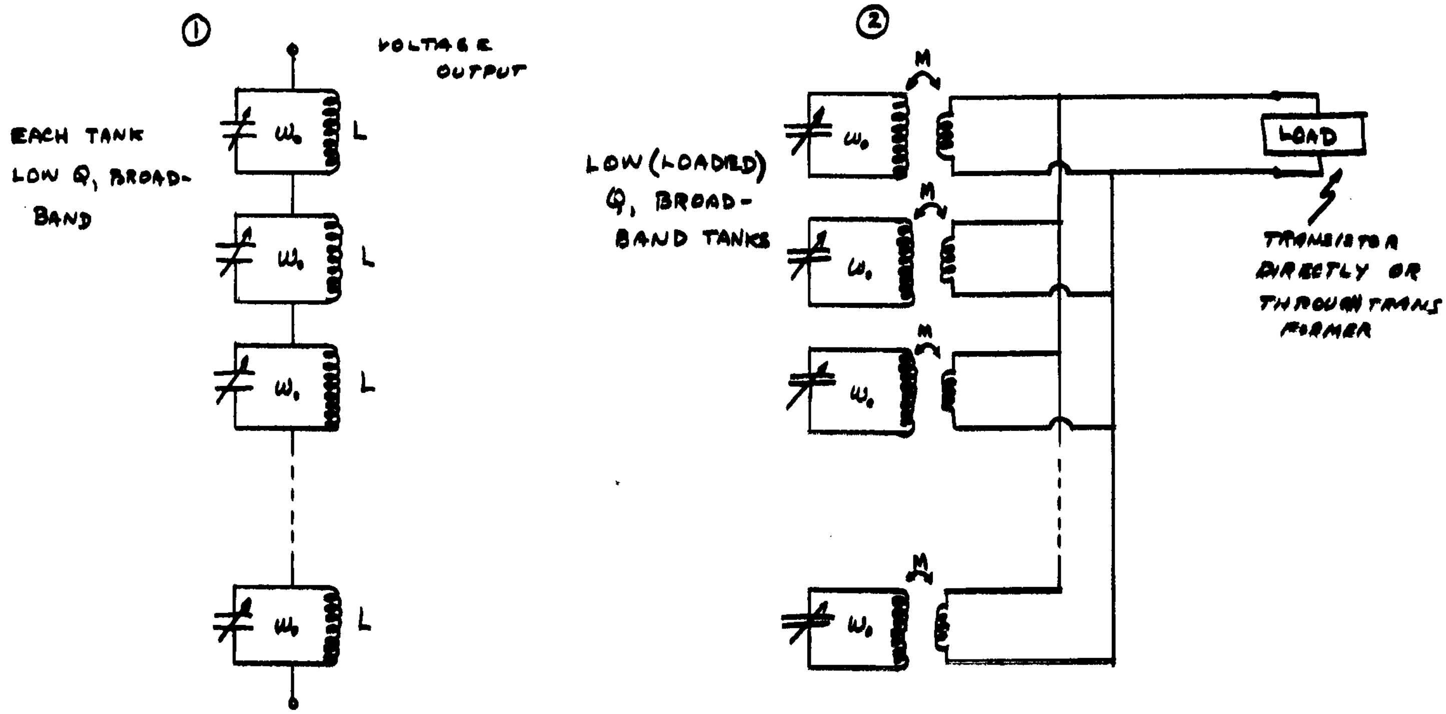
(B) Configuration (B) is much simpler. Here a group of ferrite antennas are combined in series and the entire group is resonated by a single capacitor to form a low-Q (12.5), broadband (2000 cps) circuit.



(C) Configuration (C) is similar to (B) in that a low-Q (12), broadband (2000 cps) circuit is used. It differs from (B) by the use of only one antenna with a core composed of a number of ferrite rods to produce a large area ferrite core.

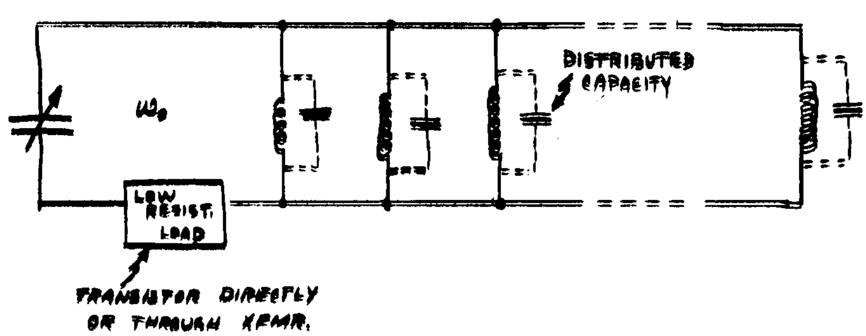


(D) ST Antenna (Series Tank Antenna)



Dual Circuits:

Dual of (B)



Dual of ST Antenna

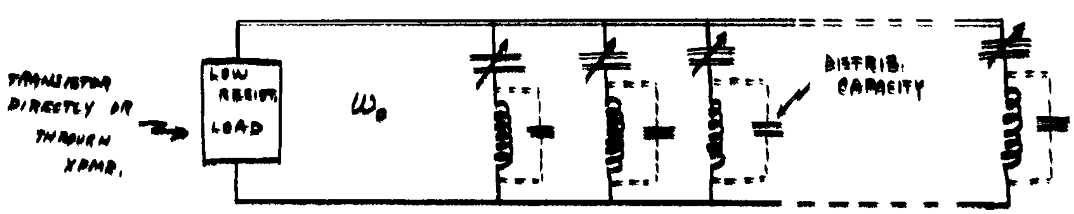


Table I

Antenna	Sensitivity Proportional To:	$\frac{\text{Sensitivity}}{\text{Thermal Noise Volts}}$ Proportional to:
A	q	q*
B (and Dual)	$\sqrt{q}$	$\sqrt{q}$
C	$\sqrt{q}$	$\sqrt{q}$
STA (and Dual)	q	$\sqrt{q}$

*Each antenna channel assumed to contain a narrow band pass filter

It would seem from Table I that antenna A is the best choice because both its sensitivity and sensitivity to noise ratio are directly proportional to q, the number of antenna coils used. This advantage is nullified unfortunatley, by three factors: a) a tuned-output transistor preamp per coil is required; b) Serious detuning effects due to mutual coupling require that the antennas be spaced so that they may act independently; c) The total number of coils that may be used is seriously limited by the maximum Q obtainable in present ferrite, e.g., $Q = q \left(\frac{\text{Center Freq.}}{\text{Total Band Pass}}\right)$; if $Q_{max} = 150$ and the relative bandpass equals

$$\frac{2000 \text{ cps}}{25 \text{ kc}} = \frac{1}{12.5} \quad \text{then } q_{max} = \frac{150}{12.5} = 12 \text{ coils.}$$

This last limitation is the deciding factor against antenna A since the number of coils in each of the other antenna arrangements is limited only by physical size and relatively small demagnetizing effects arising from mutual effects.

It is noted that the dual circuits although attractive because of their low impedance nature, have the serious disadvantage of placing distributed capacities in shunt across the output transformer thereby reducing output current. Distributed capacity plays no comparable role in the voltage-type circuits of A, B, C, and the ST Antenna (note: if capacitors had distributed inductance at V.L. frequencies the duals would be more advantageous).

The ST antenna remains as the logical choice. The problem of coupling from the ST antenna to a low impedance load (transistor or 72 ohm line) is under study and arrangements such as shown in figure (D) - (2) appear promising.

Report Prepared By:

[redacted] 25X1

Reviewed By:

[redacted] 25X1

FIRST INTERIM REPORT

on the

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

PERIOD: From the start of work to
September 1, 1956

REFERENCE: [redacted] 25X1

[redacted] 25X1

VLF FERRITE ANTENNA DEVELOPMENT PROGRAM

The following letter is submitted to report on the progress and activity in the VLF antenna development program from the start of work until September 1, 1956. The proposed methods for the development of a receiving antenna with a bandwidth of 2 kc and a center frequency of approximately 25 kc were described in detail in a "Proposal for VLF Antenna Development" which was submitted by [redacted] 25X1
[redacted] and was designated by [redacted] 25X1
[redacted] dated July, 1956. 25X1

I. PERSONNEL

Manpower was expended in the VLF ferrite antenna development program as tabulated below:

1. Engineers [redacted] 578 hours 25X1
2. Engineering Model Makers 32 hours

II. TRIPS AND CONFERENCES

A meeting was held on August 23, 1956, between Engineers [redacted] 25X1
[redacted] and the Project Engineer of the VLF Antenna Development Program 25X1
who represented the Contracting Agency. The engineers in attendance were as follows:

1. Contracting Agency
   Project Engineer
2. [redacted] 25X1

III. PROGRESS

This report, outlining the progress on the VLF Antenna Development, is divided into two sections. The first section deals with the progress in the construction of a VLF antenna system containing a number of separate demountable ferrite antennas, each tuned to a slightly different frequency, as described in detail in the "Proposal for VLF Antenna Development". The second portion of this report outlines the equipment and techniques which are being used in measuring the characteristics of the VLF antenna systems.

One of the foremost problems which exist in the development of this multi-element antenna system lies in the construction of individual ferrite antennas having a high Q. A number of different core materials and winding techniques have been used in an attempt to obtain a high Q antenna. The best antenna constructed to date has a loaded Q of 100 at 25 kc. The ferrite core of this antenna is a SECD ferrite engineering sample, labeled LNA 4B Batch 0-1 and is a 5/16" diameter rod with a length of 6". The coil is three inches in length and consists of 700 turns of AWG No. 29 wire divided into three close wound layers. This appears to be the optimum in coil design; an increase in the number of turns or in coil length produces little or no effect on the antenna Q. The graph in Figure 1 indicates that AWG No. 29 Formex wire gives the optimum in wire size at a frequency of 25 kc. Litz wire was also used, but proved ineffective at this frequency.

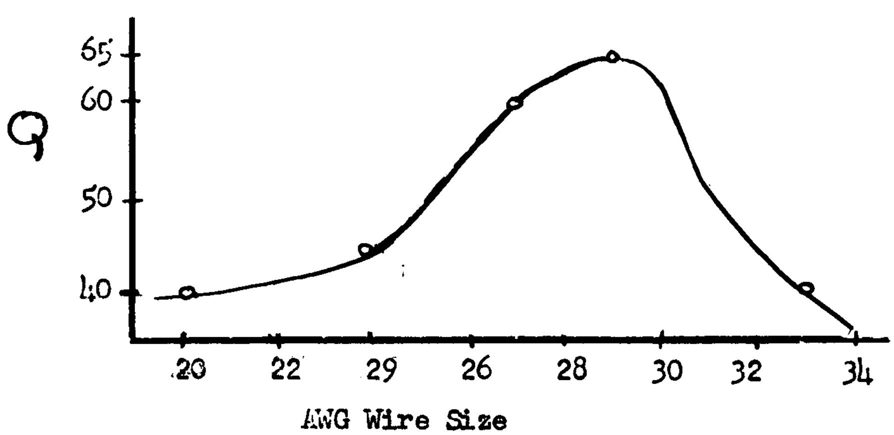


Figure 1
Effect of Wire Size on Q

A large number of ferrite antennas which are being used [redacted] were tested but proved to be ineffective at 25 kc. The greatest portion of these antennas had an unloaded Q of 20. Also a number of other ferrite materials were used (e.g. Ferramic Q and N material) but proved to be less effective.

The Q of a ferrite antenna tuned to approximately 25 kc appears to be dependent largely upon the core material used rather than the winding. Available literature indicates that certain types of powered iron cores may give better Q; these cores have been ordered. Another method for increasing the Q of a ferrite antenna is to increase its length to diameter ratio. The effect of increasing the L/D ratio is outlined in several articles on ferrite antennas.[1,2]

Another problem encountered in developing a multi-element system is the effect of mutual coupling between the individual antenna . Three antennas each having a Q of 100 at 20 kc were used in determining the mutual effect. Figure 2 shows the configuration used and Figure 3 the output which would be expected if the mutual effect was negligible.

- -

(1) H. Bloh and J. J. Rietveld, "Inductive Aerials in Modern Broadcast Receivers", Philips Technical Review, Vol. 16, January, 1955.

(2) Grimmett, C. A., "Ferrite Cored Antennas for Broadcast Band Receivers", G.E. Technical Information Series No. 53E-310, August 2, 1953.

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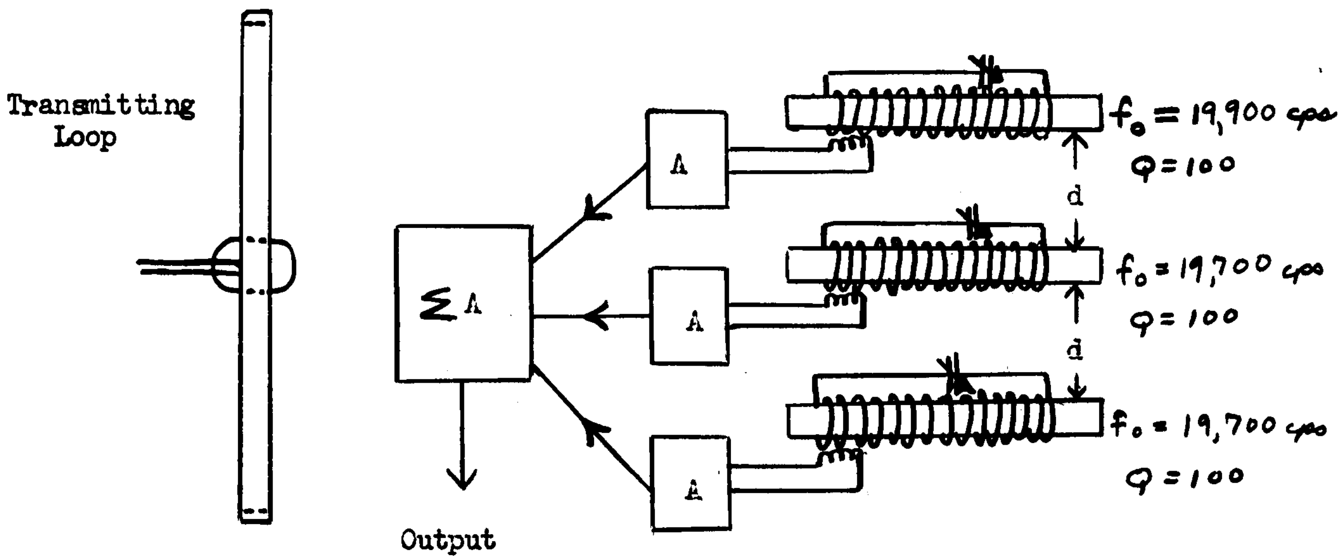

Figure 2
Test Setup for Measuring Mutual Effects

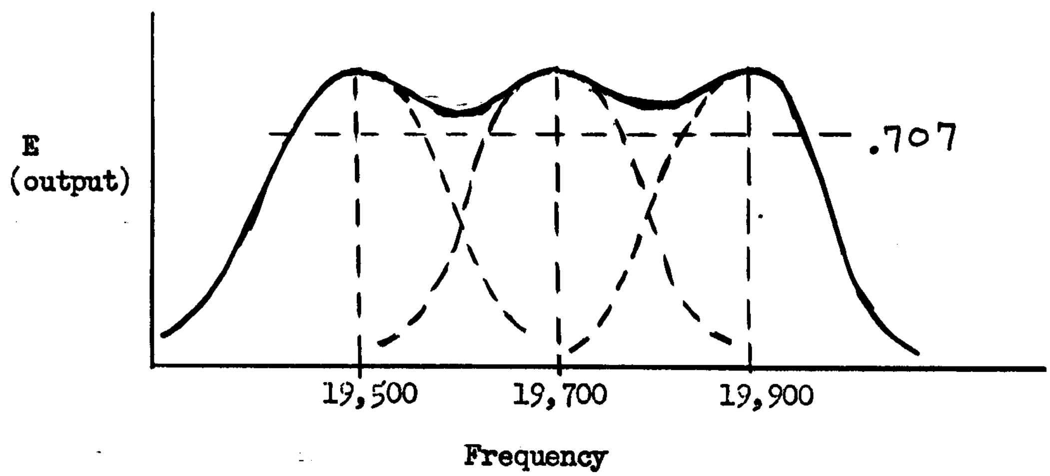

Figure 3
Antenna Response With No Mutual

With a distance of one foot or greater between antennas tuned to adjacent frequencies the output from the system corresponds with Figure 3. If the distance between the antennas is reduced, a very sharp change occurs in the response of the system. Figure 4 offers a comparison between the response of the system when spaced 1 foot, 6 inches and 3 inches.

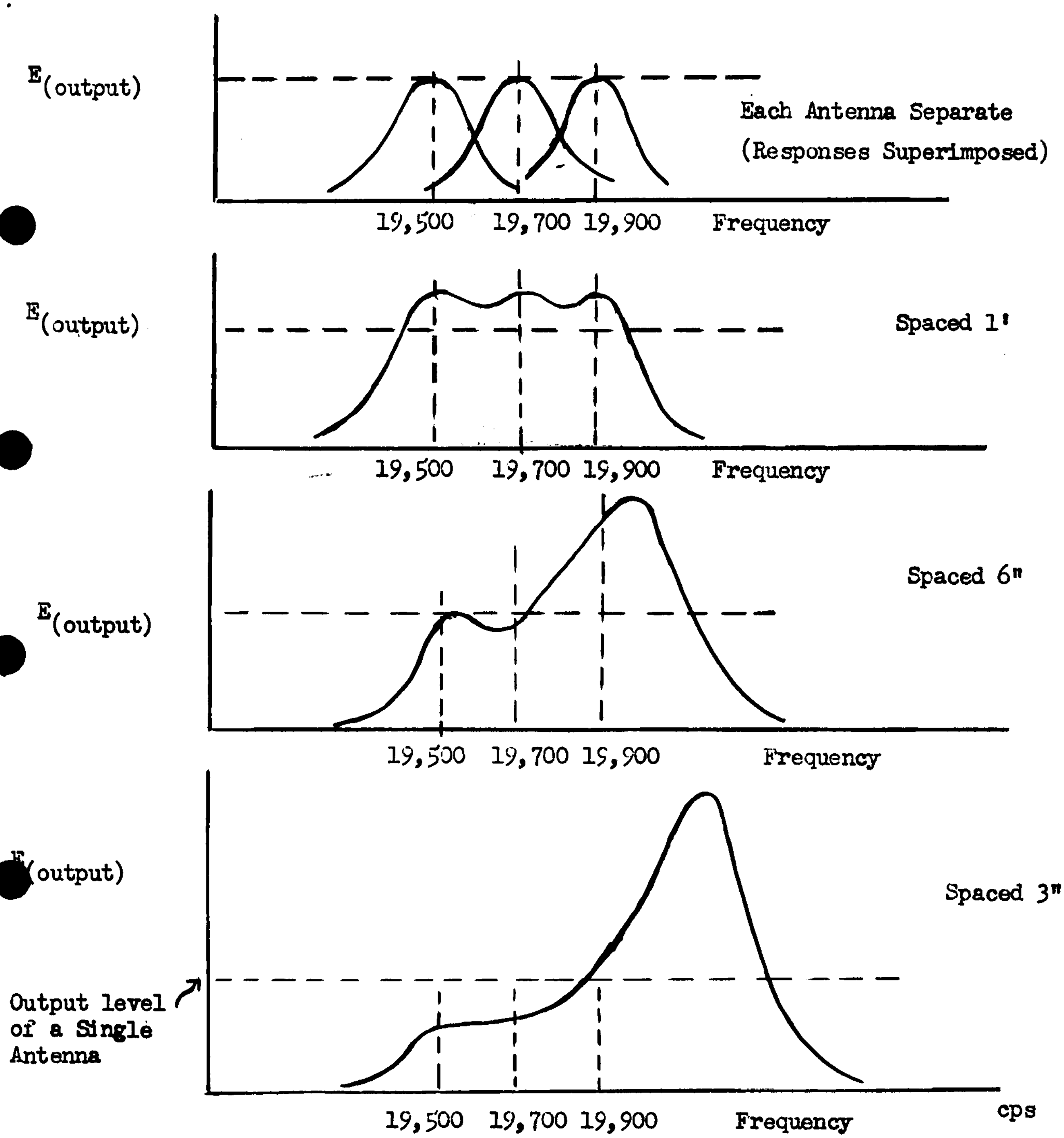

Figure 4

Antenna Response With Selected Spacings

All present tests seem to indicate that the mutual coupling between antennas spaced less than one foot apart causes a peaked response. The high frequency response of the system becomes peaked and the low frequency response is decreased.

The mutual inductance appears to be negative causing an increase in the resonant frequency of each antenna; this effect is greater on the lower frequency antennas causing their resonant frequencies to increase more than the high end. The antennas become tuned to closer frequencies and appear as one peak. It is obvious that if such an antenna system is to be used, the spacing between adjacent antennas must be at least one foot in order to overcome any effect of mutual coupling. Antennas which are not tuned to adjacent frequencies but have a relatively large frequency difference may be spaced closer than one foot without mutual coupling effects. For example, while two antennas spaced six inches and tuned to 19,900 kc and 19,700 kc respectively are noticeably affected by mutual coupling; two antennas tuned to 19,900 kc and 19,500 kc exhibit no mutual coupling effect. With the spacing between center frequencies of the separate units doubled, the distance physically between the antennas can be made approximately half of the original distance. It appears now that if the system is to have twenty separate units a design must be developed which will place the antennas in as small a package as possible and still exhibit no effects of mutual coupling between antennas.

Future work will center around the construction of a ten element system indentical to the three element system mentioned; this larger system will give the desired bandwidth. Also work will be performed on the development of individual antennas with an increased Q due to either a different core material or a greater amount of ferrite. Two other systems which were described in the "Proposal for VLF Antenna Development" will be investigated further.

Figure 5 illustrates the technique and equipment which will be used in determining the characteristics of the various systems.

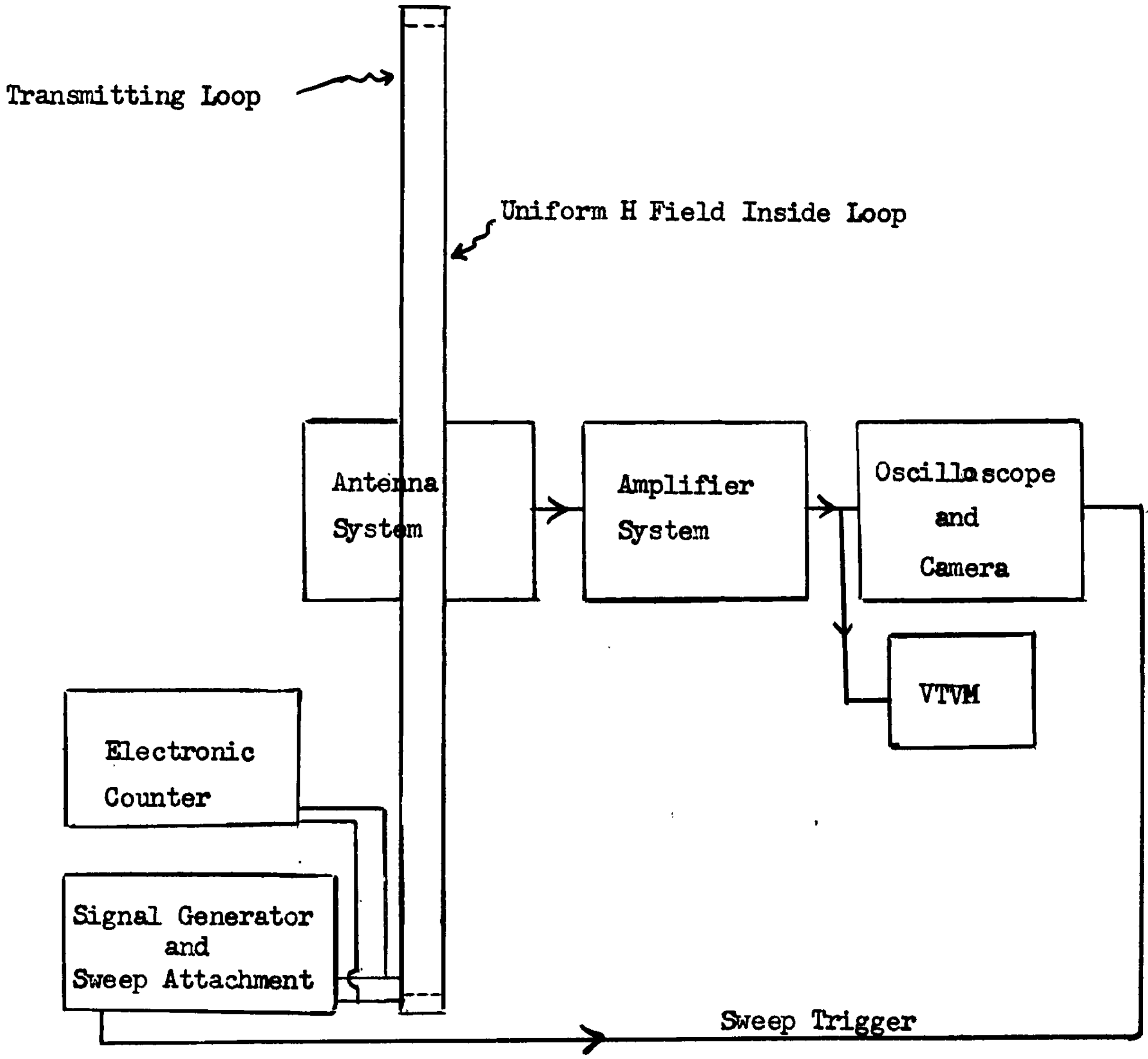

Figure 5
Equipment to Measure Bandwidth and Sensitivity of VLF Antennas

In order to test the various systems, which will be developed, a special transmitting loop has been constructed. This loop was made very large (9 ft. diameter) so that the H field inside the loop will be relatively constant and can be calculated. The sensitivity of the systems can therefore, be calculated and determined experimentally without fear of irregularities due to a nonuniform or distorted field.

In order to determine the operating frequencies accurately a Hewlett-Packard "Electronic Counter" type 522-B is being used. This counter is capable of determining the frequency to the nearest cycle with an accuracy of $\pm$ 1 cycle. With the aid of a VTVM the bandwidth of the system and of each individual antenna can be determined. Since $Q = \frac{f_o}{\Delta f}$, the Q of each individual antenna can be determined using the counter; this provides a check for all Q figures found by using a Boonton "Q-Meter" driven from an external signal generator.

A General Radio "Beat Frequency Oscillator" type 700-A has been adapted to provide a sweep of 20 kc. This allows a frequency spectrum of the antenna system to be taken easily.

Report Prepared By:

[redacted] 25X1

Reviewed By:

[redacted] 25X1